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Does Chronic Methamphetamine Use Result in a Consistent Profile of Cognitive Deficits?

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Abstract
Methamphetamine (MA) use in the United States is a significant problem that spans across the nation. While research has focused on specific domains affected by MA use there is limited research in regards to identifying a consistent cognitive profile or pattern for this population. Several studies have shown cognitive deficits in the areas of episodic memory, psychomotor speed/response inhibition, and manipulation of information, executive functioning, and fluid intelligence while other studies have presented conflicting results. The purpose of the current study is to identify whether or not a consistent cognitive profile can be determined by examining the neuropsychological performance of a sample of incarcerated men and women with a history of chronic MA use. Complete demographic and neuropsychological data were gathered from 9 individuals, consisting of 5 males and 4 females. The findings from the current study suggest chronic MA users tend to show trends of impaired performance in attention, executive planning, and mental flexibility specifically when these tasks are involved as a component of another target task (i.e. episodic memory). The overall cognitive profiles of MA users in the current study paralleled impairments seen with individuals with Attention Deficit Hyperactivity Disorder. In general, the small sample size of only 9 subjects does not allow for accurate generalization of cognitive impairments and results should be interpreted with caution, although the trends observed may provide a direction for future study.

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DOES CHRONIC METHAMPHETAMINE USE RESULT IN A CONSISTENT PROFILE OF COGNITIVE DEFICITS?

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ABSTRACT

Methamphetamine (MA) use in the United States is a significant problem that spans across the nation. While research has focused on specific domains affected by MA use there is limited research in regards to identifying a consistent cognitive profile or pattern for this population. Several studies have shown cognitive deficits in the areas of episodic memory, psychomotor speed/response inhibition, and manipulation of information, executive functioning, and fluid intelligence while other studies have presented conflicting results. The purpose of the current study is to identify whether or not a consistent cognitive profile can be determined by examining the neuropsychological performance of a sample of incarcerated men and women with a history of chronic MA use. Complete demographic and neuropsychological data were gathered from 9 individuals, consisting of 5 males and 4 females. The findings from the current study suggest chronic MA users tend to show trends of impaired performance in attention, executive planning, and mental flexibility specifically when these tasks are involved as a component of another target task (i.e. episodic memory). The overall cognitive profiles of MA users in the current study paralleled impairments seen with individuals with Attention Deficit Hyperactivity Disorder. In general, the small sample size of only 9 subjects does not allow for accurate generalization of cognitive impairments and results should be interpreted with caution, although the trends observed may provide a direction for future study.

Keywords/Subject Terms

Chronic methamphetamine use, cognitive effects, cognitive profile, neuropsychological test performance, cognitive impairment, cognitive domains.

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INTRODUCTION

Statement of the problem

Methamphetamine (MA) use in the United States is a significant problem that spans across the nation. MA is a very addictive stimulant that affects the central nervous system primarily activating the release of the neurotransmitter dopamine. The current body of research focusing on the effects of chronic MA abuse suggests chronic MA exposure can result in both neurocognitive and psychological changes. Understanding the cognitive effects of chronic MA use may play a significant role in treating individuals with a history of MA abuse. Gaining a consistent cognitive profile for chronic MA users would not only improve the efficacy of addiction treatment techniques, but also allow for treatment programs to be tailored to an individual's cognitive functioning once they have abstained. Unfortunately, current studies outlining a clear cognitive profile for this population have been limited due to inconsistent findings, difficulty gaining accurate self-report of drug abuse history, and confounding variables commonly associated with this particular population that also affect cognitive functioning (i.e. polysubstance use, traumatic brain injury, co-morbid psychiatric conditions etc.). The purpose of the current study is to identify whether or not a consistent cognitive profile can be determined by examining the neuropsychological performance of a sample of incarcerated men and women with a history of chronic MA use.

Methamphetamine use in the United States

MA is a powerful and addictive synthetic derivative of the stimulant amphetamine. The most common type of MA abused here in the U.S. is d-methamphetamine (dextro-methamphetamine) in powder form. D-methamphetamine primarily contains ephedrine, pseudophedrine, and several other chemicals depending on the type of synthesis used in

production (i.e. hydriodic acid, red phosphorous, iodine, hypophosphorous acid, and birch). The desired acute effect of MA use causes the individual to feel an increase in energy, alertness, physical activity, and libido, a decrease in appetite, sleep, and anxiety, and an intense sensation or euphoria which may last up to 12 hours depending on the type of ingestion (Barr et al. 2006). MA intoxication has a dramatic effect on many areas of the central nervous system and has many adverse health effects. The sympathetic nervous system is also stimulated by MA and produces dangerous changes in respiration and vascular performance (i.e. increases in respiration, heart rate, blood pressure, and irregular heart beat as well as hyperthermia)(Meredith et al., 2005). It comes in many forms and can be ingested orally, intranasally, inhaled, or injected intravenously. MA has several common street names such as Speed, Meth, Crystal, Ice, Tina, Crank, and Crystal Meth and is most commonly found in the powder form here in the United States.

MA abuse is an increasing problem in the United States and is becoming an epidemic not only afflicting regions of the west coast but spreading throughout both urban and rural areas of the entire country. According to the 2005 National Survey on Drug Use and Health (NSDUH), approximately 10.4 million people (4.3% of the population) age 12 and older have reported using MA at some point in their lifetime. In 2005 alone, estimates of 1.3 million people reported use within the last year and 512,000 reported MA use within the past month of being surveyed. Emergency room visits between 1995 and 2004 have increased greater than 50%, with approximately 73,000 MA abuse related visits in 2002 alone (4% of all drug related emergency room visits during 2002)(Substance Abuse and Mental Health Services Administration 2000a). Admissions for treatment of MA abuse have also increased substantially over the last decade. In 1992, approximately 21,000 individuals were admitted

for substance abuse treatment with MA as their primary substance of abuse. By 2004, the number of MA treatment admissions increased to more than 150,000 (Substance Abuse and Mental Health Services Administration 2000c).

The availability and ease of production have made MA the second most frequently abused chemical substance after marijuana in the United States and worldwide (United Nations Office for Drug Control and Crime Prevention, 2000). In the 1960's, MA pharmaceutical products were readily available and subsequently widely abused, which led to a change in U.S. legislation in 1971. MA was then placed into Schedule II of the Controlled Substance Act and injectable formulations were removed from U.S. domestic markets as a result of the high abuse potential. Underground meth labs operated by motorcycle gangs began taking control of the illicit drug production which spread throughout the west coast until law enforcement cracked down on motorcycle gangs, in turn, forcing production to move across the border to Mexico. A major resurgence of MA abuse occurred in the 1980's when Bay Area biker groups started producing MA utilizing the "P2P method" of synthesis. The "P2P" method involves the chemicals phenyl-2-propanone (P2P), aluminum, methylamine, and mercuric acid. The government passed the Federal Chemical Diversion and Trafficking Act in 1988 making it more difficult to obtain these ingredients thus making it less profitable to produce MA with this type of synthesis.

Currently, production of MA is achieved through the ephedrine/pseudophedrine reduction method which is a cheaper and more efficient technique that yields much more pure and highly addictive MA. The government has also tried to fight the production of MA in independent "home-based" labs by passing legislation to limit the amount of over the counter pharmaceuticals that contain MA precursors, although many of the ingredients are

still being obtained and smuggled across the border into the U.S. from Mexico and Canada. The illegal smuggling of these ingredients has contributed to the huge growth of production with superlabs and many small clandestine labs throughout the United States (Meredith et al. 2005). The Drug Enforcement Agency (DEA) estimates that the majority of MA on the market today comes from superlabs located both here in the U.S and in Mexico (Hunt, D., Kuck, S., &. Truitt, L., 2006). The halt of MA production has been an ongoing battle since the 1960's, yet MA continues to become an increasingly serious drug of abuse here in the United States.

Methamphetamine and the Brain

MA has high lipid solubility due to the chemical groups found in its composition which means it can penetrate the central nervous system (CNS) very rapidly across the blood brain barrier. MA is absorbed into the brain via the blood brain barrier and essentially causes a cascading release of dopamine as well as other monoamine neurotransmitters such as norepinepherine, and serotonin (Cobb et al. 2007). These neurotransmitters have a direct role in brain functioning in many different areas (i.e. frontal lobes, basal ganglia, thalamus etc.) MA primarily targets the dopamine transporter (DAT), which regulates dopaminergic transmission by facilitating the reuptake of dopamine. MA blocks dopamine reuptake but also reverses the direction of dopamine transport causing an increase in dopamine release (Khoshbouei et al., 2003). This process floods the synapse between neurons with a high concentration of dopamine in areas of the brain that regulate feelings of pleasure (Meredith et al., 2005). This pharmacological/neurobiological process is responsible for the acute desired euphoric effect of MA and also plays a primary role in addiction.

MA can cause neurotoxicity in several neurotransmitter systems but most notable in the nigrostriatal dopaminergic pathways. This pathway leads to the dopamine rich fronto-

striato-thalamo-cortical loops which become deprived of dopamine after chronic and high dose MA use. Dopamine depletion, destruction of dopamine nerve terminals, and long-term reduction in markers of dopamine terminal integrity also occur as a result of chronic and high dose MA use (Harvey et al., 2003). This neurotoxic effect takes place in and adjacent to the striatum which is a part of the brain located "under" (that is, ventromedial to) the cerebral cortex. It receives projections from most, if not all, cortical areas. Lack of dopamine in the striatum and its cortical loops can have significant effects in the planning and modulation of movement pathways as well as a variety of other cognitive processes involving executive function. The striatum and its neural connections with the frontal, prefrontal and thalamic areas of the brain play a direct/indirect role in the cognitive domains of attention, selective inhibition, working/short term memory and executive functions (i.e. planning, organization, mental abstraction, inhibition, selective attention, all of which affect other cognitive tasks such as learning and memory) (Barr et al., 2006). Chronic MA use has been extensively documented to alter the neurochemical make up of specific areas of the brain. These alterations play a significant role in the development of cognitive deficits.

Cognitive effects of chronic methamphetamine use

Several studies have indicated mild to moderate neuropsychological impairment as a result of chronic MA use. Rippeth et al. (2004), stated current estimates of approximately 40% of individuals with chronic MA dependence demonstrate global neuropsychological impairment. Although some research has been conducted in this area, most studies have not tested chronic MA users with a complete neuropsychological battery (Cobb et al. 2007). Furthermore, only specific tests within a specific cognitive domain have been implemented (i.e. Stroop Test for speed of information processing/ response inhibition, Letter Fluency for

verbal abilities, CVLT Delay for memory, Wisconsin Card Sorting Test –failure to maintain set for attention and working memory etc.) in separate studies. There are only a few studies reviewed in the literature depicting a clear and consistent overall cognitive profile of chronic MA use. There are also conflicting results among studies with varied outcomes on specific cognitive domains such as processing speed and response inhibition (Cobb et al. 2007).

Salo et al. (2006) conducted a study looking at attentional control and brain metabolite levels in MA users. The study included 36 MA abusing subjects and 16 age-matched non-substance-abusing control subjects. The inclusion criteria for the MA-abusing group were: 1) met the Diagnostic and Statistical Manual of Mental Disorders fourth edition (DSM-IV) criteria for lifetime MA dependence, and 2) were between 18 and 55 years of age. Salo and colleagues screened both groups for polydrug abuse, traumatic brain injury, HIV, and severe hepatic, endocrine, or renal disease. Both groups were given a computerized version of the Stroop attention task which is a powerful test of selective attention that requires the subject to engage cognitive control to inhibit a pre-learned but task irrelevant pattern of responding (i.e. word reading) and switch to the task relevant response (i.e. naming the ink color the words are printed in)(Stroop, 1935). Salo and colleagues used this task as a measure of attention, speed of information processing, and inhibition. Salo and colleagues found significant differences between groups in that MA users took significantly longer than the control group to read the list of colors in the second trial after reading the words in the first trial (this is referred to as the Stroop interference). Surprisingly they did not find any significant group differences in error rates within or between tasks.

Monterosso et al. (2005) also conducted a study to examine response inhibition times between MA abusers and non-MA-abusing control groups. Both groups had similar inclusion

and exclusion criteria as described in Salo et al's. (2006) study with the exception that they included two control groups: 1) smokers and 2) nonsmokers; since smoking tobacco is very common among the MA abusing population (London et al., 2004, Monterosso et al., 2005). The purpose of their study was to determine whether MA abusers would demonstrate slower Stop-Signal response inhibition times than control subjects. They also examined whether individual differences among MA abusers in response inhibition would be correlated with duration and level of MA use. Monterosso and colleagues used the Stop-Signal Task rather than the Stroop Test due to the fact that they wanted a more direct means of assessing primarily response inhibition (Monterosso et al. 2005). The Stop-Signal Task involved two concurrent tasks (Logan et al., 1997). The primary or "go" task was a choice reaction time task involving discrimination between an X and an O presented in the center of a computer screen for 1000 milliseconds (ms) following a 500 ms fixation point. The go stimulus was followed by a blank screen for 2000 ms allowing 3000 ms for response and a total trial duration of 3500 ms. Participants were asked to respond as quickly and as accurately as possible. The secondary or "stop" task involved a tone emitted from the computer. This tone followed the presentation of the go task stimulus and instructed participants to withhold their response on that particular trial. Tones occurred randomly on 25% of trials. After a successful stop trial the stop-signal delay would increase to 50ms, and after a failed trial it would decrease by 50ms. The Stop-Signal reaction time was calculated at the end of the 256 trials indicating the subject's reaction time to inhibit a response, general reaction time to the go stimulus, and error rates on go trials. Longer Stop-Signal reaction times reflect poorer inhibition (Monterosso et al., 2005).

Monterosso and colleagues found that MA abusers who recently became abstinent had slower response inhibition times on the Stop-Signal Task than both control groups, with markedly worse performance in response inhibition but no significant differences between groups in general reaction times or error rates. Results of a regression analysis indicated that response inhibition times were correlated with the amount of MA use (i.e. grams per week).

Simon et al., (2000) conducted one of the few studies found in the literature that administered a full neuropsychological battery to assess the cognitive profile of MA users. Simon and colleagues recruited 65 subjects who were currently using MA or had used MA within the past 72 hours of testing. The majority of the MA group reported using MA for more than 10 years and many of them reported experimenting with other drugs prior to using MA. Exclusion criteria were as follows: Both the MA group and control group had to pass a urine analysis for drug use (with the exception of MA for the MA group) and the control group provided a negative self report history of extensive drug use. Both groups did not differ significantly in demographic information (i.e. age, gender, education, or ethnicity).

Both groups were given a complete neuropsychological test battery which included: The Repeated Memory Test, Backward Digit Span, FAS-Verbal Fluency Test, Wisconsin Card Sorting Test (WCST), Digit Symbol subtest of the Wechsler Adult Intelligence Scale-Revised Edition (WAIS-R), Trail Making Test, parts A and B, Stroop Color Word Interference Test, and the Shipley-Hartford Test of Vocabulary and Abstract Thinking. These tests measured the cognitive domains of memory (verbal and visual recall, source memory), working memory, verbal fluency, executive functioning (abstract reasoning, reactive flexibility, perseveration, sequencing, and selective attention), psychomotor speed, and estimated premorbid general Intelligence Quotient (IQ).

Simon and colleagues found significant differences between the MA group and the control group on tasks of memory, psychomotor speed and manipulation of information, executive functioning, and fluid intelligence. More specifically, the MA group performed significantly worse than the control group on word and picture memory recall with no differences in recognition. However, the MA group produced more false positive responses on the recognition tasks. These patterns of memory deficits represent difficulties with more complex memory tasks. The pattern of poor recall and intact recognition signify a decrease in attention rather than a true "memory issue" because recall involves the individual's ability to correctly attend to, process, rehearse, and retrieve the information spontaneously. Intact recognition on the other hand, shows that the information was successfully consolidated and retrieved with the help of cueing (Simon et al., 2000).

In terms of psychomotor speed and manipulation of information, the MA group performed significantly poorer than controls on the Digit Symbol Coding and Trails B tasks. Since both tests are time based, poor performance is most likely due to the working memory components and executive aspects involved in the process of remembering and manipulating information in a timely fashion. Significant differences were also found between groups with MA users performing poorer on the Shipley-Hartford test of abstract thinking. Simone et al., 2000 states that "this test measures fluid intelligence which requires the ability to combine information in new ways and make inferences from new combinations of information" (p.226), again requiring the subject to manipulate information prior to their response.

The MA group also performed poorly on the Stroop Color Word Test much like the MA group in Salo et al's. 2006 study. No difference was observed in the initial word reading task but performance was much slower on the color word portion compared to controls.

These results may suggest MA users have difficulty focusing on the task at hand as well as inhibiting pre-learned response patterns (i.e. naming the color of the ink the word is printed in and not reading the word itself)(Barr et al., 2006; Simon et al., 2000).

Although significant differences in cognitive performance were found between groups on many cognitive tests, there were no significant differences in performance on the WCST, Shipley-Hartford vocabulary test, or the FAS verbal fluency test. Furthermore, there were no significant findings between length of MA use and test performance.

A study conducted by Kalechstein, Newton, & Green, (2003) also found several cognitive deficits in chronic MA users. Kalechstien and colleagues tested 27 non-treatment-seeking, MA-dependent subjects and 18 control subjects. Both groups were screened for history of stroke, traumatic brain injury, epilepsy, attention deficit disorder, or HIV seropositivity. Participants were also excluded if Axis I psychotic or mood disorders were present. The MA group also met DSM-IV criteria for MA dependence and was continually drug tested prior to and throughout the testing time to ensure MA users were abstinent and not experiencing withdrawal effects.

Both groups were administered a test battery which measured the cognitive domains of: attention/psychomotor speed (e.g., Trail making Test, Part A; Symbol Digit Modalities Test; Stroop Color), visuospatial skills (Rey Complex Figure Task—copy subtest), learning and memory (Rey Auditory Verbal Learning Test—learning over five trials and delayed recall; WMS-III Logical Memory—delayed recall; Rey Complex Figure Test—delayed recall), and executive systems functioning (untimed working memory, set shifting/response inhibition, fluency). The untimed working memory measures included the Letter-Number Sequencing and the Visual Memory Span—backwards subtests of the WMS-III. The set

shifting/response inhibition tasks included the Trail Making Test, Part B, and a ratio that compared performance on the Color and Word subtests to the Color-Word subtest of the Stroop test. Measures of fluency included the Controlled Oral Word Association and the Ruff Figural Fluency Test (Kalechstein et al., 2003).

Their findings revealed that the MA group performed significantly worse than the controls on tests of attention/psychomotor speed, verbal and visual learning and memory, and on specific tests of executive functioning (i.e. fluency based). No significant differences occurred in measures of visuospatial skills, untimed tests of working memory, or set shifting/response inhibition.

These findings show conflicting outcomes with Simon et al's., (2000), and Salo et al's. (2002) studies. Specifically, no impairment was noted on the Stroop test of attention and processing speed/response inhibition. Kalechstein and colleagues found significant differences between groups on measures of verbal fluency while Simon et al., 2000 did not. Both studies used the same measure to test this domain (i.e. FAS of the Controlled Oral Word Association test).

Johanson et al., (2006) also conducted a study measuring cognitive deficits in chronic MA users who were given a full neuropsychological test battery. The study examined the cognitive functioning of 16 MA dependent subjects in partial remission measured by the DSM-IV against an age, education, and IQ matched control group. Inclusion criteria for the MA group were as follows: met the DSM-IV diagnosis for MA dependence but in at least partial remission, negative urine analysis for current drug use, and no MA use within the past 3 months. Inclusion criteria for the 18 control subjects were as follows: a negative urine analysis for drug use and no history of drug dependence. Both groups were screened for

history of head trauma, seizure disorder, bi-polar disorder, schizophrenia, or current use of antidepressants.

Both the MA group and control group were administered cognitive tests measuring general cognitive ability for IQ estimates, motor performance, explicit memory that assesses both encoding and retrieval components, working memory, and executive function. Tests utilized to measure these cognitive domains were as follows: Vocabulary and Block Design subtests of the Wechsler Adult Intelligence Scale (WAIS)-III (as a general measure of IQ) (Wechsler 1997), Finger-Tapping Task (Reitan 1969), Grooved Pegboard (Klove 1964), and the Digit Symbol Substitution Test (DSST) (Wechsler 1997) (as measures of motor performance), The California Verbal Learning Test (CVLT) (Delis et al., 1987) and the Paired Associates Learning Task (PAL) (Robbins et al. 1994, 1998) (as measures of explicit memory),and the Trail Making Test (parts A and B; Reitan 1958) and COWA (FAS) (as measures of executive functioning).

Cognitive test results only showed a significant difference between the MA group and the comparison group on the Digit Span Substitution Task and the CVLT. This pattern of performance suggests that MA users have difficulty with accuracy of information manipulation as evidenced by poorer performance on the DSST. This finding is similar to that of Simone et al., (2000) and Kalechstein et al., (2003).

Significant differences were also noted between groups on the cued and noncued short and long delay trials of the CVLT suggesting that chronic MA users are able to learn new information but have retrieval difficulties. These difficulties are more likely due to a disruption in the organizational and tactical components of memory encoding and retrieval which are heavily influenced by attention, and executive functions (Cobb et al., 2007).

Surprisingly, no significant differences were found between groups on any other measures given. These results add to the conflicting research in the current literature regarding cognitive effects of chronic MA use.

The inconsistent findings evident in the literature prompted Cobb et al.'s (2007) meta-analysis of studies focusing on the long-term neurocognitive effects of MA. Cobb and colleagues included studies with participants 18 years of age or older; members of the MA group reported lifetime MA use with MA as their primary substance of use; healthy comparison subjects did not have a history of stimulant abuse or neurologic or psychologic illnesses; outcome measures included at least one neuropsychological test; and sufficient data were provided to calculate effect sizes.

A two-level mixed effects model was used to study the variability of effect sizes between studies and the association between explanatory variables and effect sizes. In terms of results, the meta-analysis generally supported the overall contention that MA use significantly affects neuropsychological impairment.

Specifically, Cobb et al. (2007) found significant deficits with medium magnitude in several cognitive processes including episodic memory, executive functioning, complex information processing speed, and psychomotor performance. Smaller effects were identified in the areas of attention/working memory, and language abilities.

Impairment in episodic memory was linked with medium to large effects in MA users. Cobb et al. (2007) stated that MA user's deficits in episodic memory were complicated by the fact that other abilities are involved in these cognitive processes (i.e. encoding, consolidation, and retrieval) and can all be affected by processes such as attention, working memory, and executive approach. Evidence for this assumption was found in the slightly

larger effect size for learning (or retrieval) rather than consolidation. Again, the dynamic relationship between accuracy in attending to, organizing, and accurately retrieving information autonomously vs. displaying consolidation through cued recognition was emphasized. As expected, the meta-analysis also identified significant effect sizes for MA users with deficits in executive functioning particularly in cognitive set shifting and response inhibition. Much of the research has demonstrated MA use causes deficits in abstract reasoning, planning, behavioral flexibility, and attention all of which affect other domains of cognitive functioning (i.e. episodic memory). Barr et al. (2006) notes the parallel between these deficits and Attention Deficit Hyperactivity Disorder (ADHD).

Processing speed of information and psychomotor tasks with this population also yielded a significant effect size. A slight difference was apparent in the meta-analysis between these two abilities with processing speed of information having a slightly larger effect size than the latter. Cobb et al. (2007) hypothesizes that tasks which require a component of higher level cognitive abilities are more sensitive to chronic MA use than less demanding speeded tasks. This is evident in test performance on the DSST vs. the word reading portion of the Stroop test. The DSST measures the accuracy of information manipulation in a time sensitive task as opposed to the word reading portion of the Stroop test which requires no manipulation of information but is more of a "pure" test of speed of processing. Several studies previously reviewed also support this notion (i.e. Simone et al., 2000; Kalechstein et al., 2003).

Cognitive deficits in attention, working memory, and language tasks were identified as having small effect sizes. Cobb and colleagues hypothesize chronic MA abuse/dependence may cause slight deficits in these areas partially as a result of more significant impairment in

the areas of executive functioning and information processing speed abilities. The literature review also suggests a more consistent pattern of deficits in these latter functions.

Although the results of several studies displayed conflicting outcomes, the studies reviewed in the literature in conjunction with Cobb et al.'s 2007 meta-analysis provide a general overview of some consistent cognitive deficits observed in chronic MA users. More research is needed to delineate a clear and consistent cognitive profile of impaired cognitive functioning in chronic MA use. The cognitive domains of episodic memory, executive functioning, complex information processing speed, and psychomotor performance tend to show the most consistency and greatest effect size between studies.

Purpose of the Present Study

After reviewing the literature it appears evident that MA use is a rising concern with its ease of production, widespread abuse, and documented negative physical and cognitive consequences. Understanding and identifying the cognitive profile of individuals with long-term MA use may provide insight to treating their addiction as well as any secondary or co-morbid psychiatric conditions since at this time cognitive behavioral interventions are being implemented in the treatment of this population (Simon et al., 2000). Research in the area of long-term cognitive effects of chronic MA use has been limited with conflicting outcomes with difficulties inherent to the population due to the high rates of recidivism, polydrug use and accuracy in self-report (Barr et al., 2006). While research has focused on specific domains affected by MA use there is limited research in regards to identifying a consistent cognitive profile or pattern for this population. Several studies have shown cognitive deficits in the areas of episodic memory, psychomotor speed/response inhibition, and manipulation

of information, executive functioning, and fluid intelligence while other studies have presented conflicting results.

The purpose of this study is to further the body of literature regarding the long-term cognitive effects of chronic MA use with an emphasis on identifying a consistent cognitive profile for this population. Conflicting results between studies that have used similar or identical measurements of specific cognitive functions provide a sound rational for expanding this particular area of research. Given that previous studies have identified several consistent cognitive domains that seem to be affected by long term MA use, it is hypothesized that these findings will be generalized in a population of incarcerated chronic MA users who have received a full battery of neuropsychological tests. Identifying a consistent profile of neuropsychological deficits could prove invaluable in the development and delivery of addiction and recovery programs, psychotherapy, and vocational rehabilitation for this population.

METHOD

Participants

One hundred (n = 100) adult residents at the Washington County Community Corrections Center (WCCC) volunteered to participate in neuropsychological testing for research purposes. WCCC is a minimum security transitional facility that houses offenders who have violated the terms of their probation or parole, who have been allotted a jail sentence of 12 months or less, or who are mandated to serve their sentence while in an intensive drug and alcohol rehabilitation program (i.e. the judge sentenced them to alternative sanctions). As residents were admitted into WCCC between May and October of 2005, they were informed of the project and given the opportunity to participate. Given the difficulties inherent in studying the MA user population, strict inclusion and exclusion criteria were developed in an attempt to minimize confounding variables that may affect cognitive performance. Only individuals who reported a history of MA use with MA as their primary drug of choice were included in the current study. Exclusionary criteria included lack of fluency in English, active psychosis or agitation that could prevent test completion, reported history of traumatic brain injury, stroke, cancer, seizures, psychiatric diagnoses (i.e. attention deficit-hyperactivity disorder, learning disability etc.) and history of significant polysubstance abuse (i.e. history of substance use including: other Stimulants, hallucinogens, and heroin or other opiates. Nine (n = 9) subjects of the 100 individuals who participated in receiving neuropsychological testing met the criteria described above.

Complete demographic and neuropsychological data were gathered from the 9 participants, consisting of 5 males and 4 females (i.e., final sample: n = 9). Of these participants, 77.8% were Caucasian and 22.2% were Hispanic. The mean age of the sample

was 31.56 (*SD* =4.98), and the average level of education was 11.4years (*SD* =1.13). Participants in this sample were primarily single 55.6(%), although others were married 11.1(%), and divorced 33.3(%). Participant demographics are summarized in Table 1 below.

Table 1

Gender, Ethnicity, Mean Age, and Education of the Clinical Sample

Trait	Group	n	(%)
Gender	Male	5	55.56
	Female	4	44.44
Ethnicity	Caucasian	7	77.78
	Hispanic	2	22.22
Mean Age	31.56 years old		
Mean Education	11.4 years		

Note: Total Sample Size N = 9

Measures

All participants were given a battery of tests measuring the cognitive domains of: estimated premorbid IQ, attention and concentration, psychomotor speed, processing speed, working memory, memory, and executive functioning. Tests used to measure these cognitive domains include: Wechsler Test of Adult Reading (WTAR): Demographics – Predicted Premorbid Full Scale Intelligence Quotient; Wechsler Abbreviated Scale of Intelligence (WASI): Block Design subtest, Wechsler Adult Intelligence Scale – 3rd Edition (WAIS-III): Digit Span subtest; Wechsler Memory Scale – 3rd Edition: Spatial Span subtest; Woodcock Johnson III – Test of Cognitive Ability: Pair Cancellation subtest; Integrated Visual Auditory (IVA) Continuous Performance Test; California Verbal Learning Test - 2nd Edition (CVLT-II); The Rey-Osterrieth Complex Figure Test (ROCF); Delis-Kaplan Executive Function

System (D-KEFS): Trail Making subtest, Color-Word Interference subtest, and Tower subtest.

WASI: Block Design subtest

Visuomotor construction ability was determined from the Wechsler Abbreviated Scale of Intelligence (WASI; The Psychological Corporation, 1999) Block Design tasks. The WASI as a whole is designed to be a brief version of intelligence assessment that yields Full Scale (FSIQ), Verbal IQ (VIQ), and Performance IQ (PIQ) estimates. It has proven to be a valid measure of assessing verbal and performance capacity and has been used in clinical situations and research studies where an estimate of intelligence is sought when time or other constraints forestall the administration of the full Wechsler Adult Intelligence Scale (WAIS-III). The verbal and performance estimate can be made using either two or four of the subtests for children and adults from ages 6 to 89. The WASI was standardized on a representative national sample of 2, 245 children and adults. The manual provides reliability and validity information with reliabilities above .80 for measures of split-half reliability, internal consistency, stability, and test effects. More specifically, the reliability coefficients range from .93 to .98, with an average of .96. The correlation coefficient between the WASI Full Scale IQ and WAIS Full Scale IQ is .87. Validity information correlating the WASI with other tests is also included in the manual. The WASI is considered to be the recommended instrument for brief and accurate assessment of general intellectual functioning (Strauss et al., 2006). The Block Design subtest itself is a test within the WASI that measures visuoconstructional abilities within a time limit. It involves visual construction, planning, visual perceptual abilities, and psychomotor speed. The Block Design subtest is also part of the WAIS-III battery and is virtually identical with no significant differences

between them. No reliability coefficients were reported specifically for the WASI Block Design subtest, although the same subtest within the WAIS-III yielded high reliability coefficients between the ranges of .80 and .89 for both internal consistency and test-retest effects.

WAIS-III: Digit Span subtest

The WAIS-III is one of the most common measures used in neuropsychological batteries. It was designed to assess the overall level of one's intellectual functioning and is commonly referred to as "the gold standard" in intelligence testing (Strauss et al., 2006). The WAIS-III also provides measures of verbal IQ, performance IQ and four other factors of intelligence (i.e. working memory, processing speed, verbal comprehension, and perceptual organization). The test consists of 14 subtests that tap into numerous cognitive abilities that make up the four factors previously listed. Normative data was collected from a standardized sample of 2450 people between the ages of 16 to 89. The sample was stratified according to age, gender, race/ethnicity, education, and geographic region from the 1995 US Census. The WAIS-III FSIQ score is reported to have very high internal and test-retest reliability coefficients from .95 to .98.

The Digit Span subtest of the WAIS-III is a measure of auditory/verbal attention and working memory. The Digit Span test is divided into two trials with the first trial assessing one's ability to simply repeat a number sequence in the same order as presented (Digit Span Forwards) assessing simple auditory/verbal attention. The second portion of the test requires the examinee to repeat the number sequence in reverse order (Digit Span Backwards) also assessing their working memory abilities. The Digit Span subtest has a very high internal

consistency with reliability coefficients greater than .90. Test-retest reliability is also high with reliability coefficients in the range of .80 to .89.

WMS-III Spatial Span subtest

The WMS-III (Psychological Corporation, 1997) is a general test of memory that is also co-normed with other Wechsler test (i.e. WAIS-III, WIAT-II). The WMS-III includes eight primary indexes eight Primary Indexes (i.e. Auditory Immediate, Auditory Delayed, Visual Immediate, Visual Delayed, Immediate Memory, Auditory Recognition Delayed, General Memory, and Working Memory) calculated by performance on 14 subtests (WMS-III Technical Manual, 1997). The WMS-III was standardized from 1250 individuals from 16 to 89 years old. The normative sample was divided into 100 subjects in 13 age groups. The sample was also stratified against the 1995 US Census for age, gender, and race/ethnicity. Median reliability of the subtest scores in the primary indexes across all age ranges is high at .81. The Spatial Span subtest of the WMS-III is similar to the Digit Span subtest of the WAIS-III and WMS-III as they both measure attention and working memory abilities. The significant difference between the two subtests is the modality in which they are presented (i.e. visual information vs. auditory information). Spatial Span measures one's ability to attend to and hold visual information in a sequenced pattern and in the second portion of the test (Spatial Span backwards), manipulate that information before giving a response.

D-KEFS: Trail Making, Color Word, and Tower subtests

Executive functioning was measured with several subtests of the D-KEFS. The D-KEFS (Delis et al., 2001) is a battery of tests that can be given as a whole battery or separated and utilized as single subtests to determine executive dysfunction. The D-KEFS was normed with 1750 subjects, ages ranging from 8 through 89 years of age. The normative

sample is representative of the U.S. population including age, gender, ethnicity/race, and geographical region. Reliability for specific subtests used in the current study (i.e. Trail Making, Color Word, and Tower subtests) yielded internal consistency ranging from low to adequate. The highest reliability coefficients of .70 to .79 were noted for the number and letter sequencing condition for the Trail Making test and color naming and word reading conditions of the Color Word subtest. The Tower test total achievement was in the .60 to .69 range for internal consistency. Test-retest reliability for Trail Making, Color Word, and the Tower subtests also ranged from low to adequate reliability with Trails- motor speed condition and Color Word-color naming and inhibition conditions with reliability coefficients between in the range of .70 to .79 (Strauss et al., 2006).

The Trail Making subtest is a test that measures different cognitive processes such as visual scanning, number sequencing, letter sequencing, number-letter switching, and motor speed. Similarly, the Color Word Interference test is also designed with several conditions measuring different cognitive abilities including inhibition of overlearned responses and mental flexibility. The Tower subtest measures planning abilities, rule learning, and inhibition (Strauss et al., 2006).

WJ-III Cognitive: Paired Cancellation subtest

The Woodcock Johnson-III Test of Cognitive Abilities is an extensively normed test of cognitive abilities based on the Cattell-Horn-Caroll theory of intelligence (Strauss et al., 2006). The WJ-III Test of Cognitive Abilities measures general intelligence, factors representing broad cognitive abilities, and more specific abilities of cognitive functioning. The test was normed based on the performance of 8818 subjects within 100 different geographical regions across the United States. The sample was randomly selected from a

stratified population representative of 10 specific community and individual variables as well as 13 different socioeconomic status variables. These variables were approximated from the U.S. 2000 Census projections. Split-half reliabilities and Rasch analysis procedures were used to calculate the reliability of speeded subtests and subtests with multipoint scoring (Strauss et al., 2006). Internal reliability for these tests range from .80 to .97. Subtest score reliabilities are noted to be generally high.

The Paired Cancellation subtest of the WJ-III was used to measure attention, processing speed, and some aspects of executive functioning. Test demands include both sustained attention and response inhibition while circling target items presented in the correct sequence in a timed fashion. The Paired Cancellation subtest has been found to have marginal test-retest reliability with coefficients in the .60 to .69 range. Interrater reliability data for the test of cognitive ability is not provided in the WJ-III manual although information regarding test validity is extensive and can be found in the WJ-III technical manual (Strauss et al., 2006).

CVLT-II

Auditory/verbal episodic memory was measured using the California Verbal Learning Test-2nd Edition (CVLT-II). The CVLT-II is a test of auditory/verbal memory and learning, but also provides measures of how information is learned and retrieved (Delis et al., 2000). The test itself measures an individual's ability to learn a shopping list of 16 words over 5 trials. A second list of 16 words (list B) is administered as an interference trial which is then followed by immediate recall of the first list (list A) that was repeated 5 times. A short delay-cued-recall trial of list A is administered in order to assess whether semantic cueing improves the individual's recall (also providing a strategy for recalling 16 words in future trials). After

a 20 minute delay, the subject is required to recall as many words from list A as possible. The long-delay free recall is then followed by a long-delay-cued recall trail. Finally, a yes/no recognition and optionally forced choice trial is administered.

The CVLT-II normative data was gathered through 1087 subjects between the ages of 16 to 89 and educational backgrounds ranging from 9 to 16 years of education. The normative population was matched to the 1999 US Census data with regards to race/ethnicity, education, and region (Strauss et al., 2006). Normative data is age and gender corrected and listed in *z* scores with a mean of 0 and standard deviation of 1. Internal consistency was determined through three approaches. First, split-half reliability was very high for the total normative sample (r = .94) and (r = 96) for the mixed clinical sample. Coefficient alphas calculated on the word category scores across trials was also high for both the standardized and mixed clinical samples (r = 82, r = 83). The third approach looked at the frequency in which the 16 words were recalled across the five learning trials. Reliability was .79 and .83 for the standardized and mixed clinical samples, respectively. Test-retest reliability of the CVLT-II is high for trials measuring overall achievement but low for process-oriented components of the test (Strauss et al., 2006).

ROCF

Visually memory was measured with performance on the Rey-Osterrieth Complex Figure Test (ROCF). The ROCF test consists of a copy trial, followed by an immediate recall of the figure copied. Thirty minutes later, a delayed recall trial and recognition trial are administered. The ROCF test is one of the oldest and most commonly used neuropsychological measures in the field (Strauss et al., 2006). Besides measuring episodic visual memory, the ROCF also provides useful information regarding planning abilities,

organization, motor, and perceptual abilities. The ROCF manual lists normative data for individuals aged 6-89 with approximately 14 yrs of education for the adults in the sample. Individuals in the normative sample were approximately half male and half female, and consisted of university students and volunteers from suburban communities primarily recruited from north central and western areas of the U.S. No information regarding race or ethnic distribution is reported in the manual. Although the method of administration, scoring, and normative data. Internal reliability was determined by split half and coefficient alpha methods and yielded reliability coefficients of .60 for the copy and more than .80 on both the immediate and delayed recall conditions. Interrater reliability described by Meyers & Meyers, (1995a) high interrater reliability (>.90) for ROCF total scores (Strauss et al., 2006).

Interestingly, factor analytic and correlational studies suggest the ROCF test is a valid measure of visual-constructional abilities and memory with less evidence of which executive processes are involved within the test. It has been noted that the majority of healthy individuals utilize a holistic or gestalt approach to perceptual organization as opposed to a local or piecemeal approach will have better recall (Strauss et al., 2006).

Integrated Visual and Auditory Continuous Response Test

Sustained attention and response inhibition was measured with the Integrated Visual and Auditory Continuous Response Test (IVA CPT). The IVA CPT is a computerized test which requires two types of responding (Stanford & Turner, 1995). First, the respondent is required to respond to auditory and visual target stimuli in a speeded fashion but maintaining as much accuracy as possible. Second, the respondent must inhibit a learned response (i.e. clicking the mouse button or space bar immediately after seeing a letter of the alphabet) and implement a specific response rule (i.e. not pressing the button after seeing an X on the

screen) to avoid making errors of commission. The two primary Full Scale Quotient Scores (response inhibition and attention) are made up of three scales each; prudence, consistency, stamina, and vigilance, focus, and speed. The IVA provides detailed measurement of the responder's response characteristics including impulsivity, response inhibition, errors of omission and commission, ability to stay on task, response speed, and reaction time. The IVA CPT normative data was gathered from the performance of 1700 individuals, ages ranging from 6 to 99, with the largest numbers of sample subjects falling in the range of 30 to 40 years of age. Internal consistency and standard error of measurement are not provided within the test manual.

Procedure

The original data collection was approved by Pacific University's Institutional Review Board (IRB proposal 04-79). Assessment measures were administered by Pacific University's School of Professional Psychology graduate students who were specifically trained for the project. WCCC residents who agreed to partake in this research project were assured that participation was entirely voluntary. Students reviewed informed consent with each participant prior to testing, and participants were advised that they could discontinue testing at any time. IRB approval was also obtained prior to the use of this archival data for the current study.

Each participant was given a basic demographic questionnaire prior to testing; this information was supplemented by a review of each offender's WCCC file. If there were discrepancies between these two sources, the information in the offender's file was utilized with the exception of self-reported ethnicity. Each offender's file was also reviewed in order to document their adult criminal history, including number of arrests, date of first arrest, and

all convictions in the state of Oregon. Each offender was also given a drug abuse screening test prior to testing.

After test administration and scoring, all data were reviewed by two senior graduate students for quality assurance purposes. Test data were then coded by doctoral students familiar with administration and interpretation of test scores. Data collectors received training to ensure reliable and consistent data collection prior to and periodically throughout the data collection process. The data were first entered into a database by a research assistant and one other data collector using Microsoft Access. It was then transferred to the Statistical Package for the Social Sciences (SPSS) for data analysis. The data were checked for accuracy several times by both the research assistant and the other data collectors.

For the purpose of this study, descriptive statistics were analyzed using Statistical Package for the Social Sciences (SPSS) for each chronic MA user. Each subject's neuropsychological test performance measuring the cognitive domains of attention and concentration, psychomotor speed, processing speed, working memory, memory, and executive functioning were compared to their estimated premorbid Intelligence Quotient (IQ). Estimated premorbid IQ was established using the Wechsler Test of Adult Reading - demographic prediction of WAIS-III FSIQ scores. The WTAR demographic prediction of estimated premorbid IQ takes into account demographic variables including age, education, sex, and ethnicity and is based on a nationally representative stratified sample closely matching the U.S. population proportions reported by the U.S. Bureau of the Census for 1995. The use of this demographic method has the advantage of being applicable to a wide range of individuals and is not subject to a decline in cognitive performance or clinical conditions (e.g. long-term exposure to MA use, dementia etc.).

The rationale for using the WTAR demographics predicted estimate of premorbid IQ as opposed to performance-based techniques was to minimize the effects of suboptimal effort since performance-based measures are commonly confounded, particularly in the medical-legal context (Strauss et al., 2006).

RESULTS

Neuropsychological performance on tests measuring different cognitive domains (i.e. attention and concentration, auditory and verbal memory, executive functioning, processing speed, language, visuospatial construction abilities, and motor speed) are commonly compared against an individual's estimated premorbid IQ in order to determine strengths, relative weaknesses, and patterns of decline. Individual performance of 9 subjects in the MA user sample was examined for intrapersonal differences between their estimated premorbid IQ' s and their performance on tests measuring cognitive domains believed to be most affected by chronic MA use.

Neuropsychological Performance by Cognitive Domain

Estimated Pre-Morbid IQ

The Wechsler Adult Test of Reading demographic prediction of IQ identified 8 of the 9 (88.89%) individuals within the MA user sample with an estimated premorbid IQ in the average range. One subject had an estimated premorbid IQ which fell in the low average range. Each of the individual's estimated Premorbid IQ is indicated on Tables 2 through 26. Test scores that fall 1 standard deviation (SD) below premorbid estimates of IQ may represent relative weaknesses but care must be taken in interpreting these differences as approximately 15% of intact individuals tend to display scores at least 1 SD below test means. Identifying impaired performance by a 1 SD difference increases the risk of false positive identification. Utilizing a more stringent 2 SD difference is statistically significant but increases the possibility of false negative identification of impairment. Individuals who show truly impaired performance may not be correctly identified with such stringent cut offs (Leezak et al., 2004). For the purpose of this study, impairment was classified by a 1.5 or

greater SD difference between individual test scores and estimated premorbid IQ in order to reduce both false positive and false negative classification of impairment.

Motor Speed

Motor speed was measured using the D-KEFS Trials: Condition 5, a test which requires individuals to accurately connect circles plotted along a dotted line from the beginning to an endpoint as rapidly as possible. Only one of the 9 (11%) individuals showed significant impairment in motor speed in comparison to their estimated premorbid IQ. Results are summarized in Table 2.

Visuoconstruction Abilities

Visuoconstruction abilities were measured by performance on the WAIS-III Block Design subtest and the ROCF copy trial. Table 3 illustrates that only one individual of the total sample (n = 9) showed significant impairment on the block design subtest, a test which involves physically manipulating blocks with patterns to recreate a target pattern by putting them together in a timed manner. In contrast, 7 out of 9(77.89%) individuals performed $\geq$ 1.5 SD below their estimated premorbid IQ on the copy trial of the ROCF (see Table 4). The ROCF copy trial is not timed and involves accurately copying a figure and requires both visuoconstruction abilities and a good executive approach to successfully complete the task.

Attention and Concentration

The cognitive domain of attention and concentration was measured by performance on the IVA Continuous Performance Test (CPT), WAIS-III Digit Span Forward subtest, and the WMS-III Spatial Span Forward subtest. No significant impairment in performance among all individuals in the sample was noted for either of the Digit Span Forward or Spatial Span Forward Subtests. Both Digit Span Forward and Spatial Span Forward measure simple

attention span in either an auditory/verbal (digit span) or visual (spatial span) modality. Conversely, performance on the IVA CPT revealed that half (50%) of the sample (n = 8) who completed the IVA CPT made a significant number of errors of omission (not responding to target auditory or visual stimuli) noted in Tables 20 & 21. The total sample mean performance compared to normative data on the scales of auditory and visual vigilance was in the borderline (70.75) and impaired (69.63) clinical ranges respectively (see Table 27). Furthermore, performance on scales of auditory and visual speed (a measure of average reaction time to correct target stimuli) on Tables 23 and 24 display 3 out of 8(37.5%) people in the sample with slowed reaction times to auditory stimuli and 6 out of 8(75%) subjects had slowed reaction times to visual stimuli. Table 25 shows that two individuals (25%) had impaired performance on the IVA full-scale response control quotient, a measure that combines the three response control primary scales (prudence, consistency, and stamina). When examined alone, impairment on specific measures of both auditory and visual prudence, consistency, and stamina were identified for only 1 of 8(12.5%) subjects in the sample. Please refer to Tables 14 through 19 for performance on the response control primary scales. Impaired performance was also noted for 3 of 8(37.5%) individuals in the sample on the IVA full-scale attention quotient. The full-scale attention quotient includes the 3 primary attention measures including vigilance, focus, and speed (see Table 26). Of the 3 primary attention measures, Visual Focus was shown to have the smallest frequency of impaired performance with only 1 of 8 (12.5%) individuals in the sample.

Executive Functioning

Executive functioning was measured by performance on the D-KEFS Trail Making Test: Condition 4 (Number – Letter Switching), Color -Word Interference Test: Condition 4

(Inhibition/Switching), and the Tower Test. Intact performance was noted for all individuals (n = 9) on the D-KEFS Trails Number – Letter switching subtest, and the Tower subtest. Both subtests require a motor component and involve set shifting/mental flexibility (Trails) and spatial planning, rule learning, and the inhibition of impulsive and perseverative responding (Towers). Impaired performance was found with one individual (see Table 5) on the Color – Word Switching trial. The Color – Word Switching trial requires an individual to switch back and forth between naming ink colors and reading words. This trial measures both inhibition and cognitive flexibility, both of which are thought to be significantly affected by chronic MA use.

Working Memory

Working memory performance was measured on the WAIS-III Digit Span Backwards subtest and the WMS-III Spatial Span Backwards subtest. All 9 individuals in the sample showed intact working memory abilities on both the Digit Span Backwards (a test which requires an individual to attend to, hold, and manipulate auditory/verbal information) and Spatial Span Backwards (a test which requires an individual to attend to, hold on to, and manipulate visual stimuli) subtests.

Memory

Auditory/verbal episodic memory was measured by performance on the CVLT-II. The CVLT-II provides useful information regarding an individual's overall learning, recall and retrieval, and response characteristics such as false positives and perseverative responses (Strauss et al., 2006). Analysis of individual performance on the CVLT-II for the 9 self reported chronic MA users revealed very low frequencies of impaired performance when compared to their estimated premorbid intelligence levels. Tables 8 through 13 indicate that

only 11% or 1 out of 9 individuals in the total sample (n = 9) showed a ≥ 1.5 SD discrepancy between estimated premorbid IQ and measures of total learning (trials 1-5 total score), learning an interference list (List B), short delay free and cued recall, long delay free recall and false positive responses. All other measures of the CVLT-II including recognition, long delay cued recall, and perseverative responses were in the normal range of variability among all 9 subjects. The most significant pattern that emerged from further exploration revealed that a trend of lower scores was observed for 5 of the 9 individuals on the interference trial (List B) although only one was at the 1.5 SD level. Results are indicated on Table 9. Decreased performance on the interference trial may suggest a slight decrease in mental flexibility among this sample group. These findings are consistent with previous research suggesting chronic MA use can affect certain aspects of executive functioning such as mental flexibility.

Episodic visual memory was measured through the ROCF Test immediate and delayed recall trials (see Tables 6 & 7). A ≥ 1.5 SD discrepancy was noted for 2 out of 9(22.22%) of the MA users on the immediate recall of the complex figure design after a brief 3 minute distraction. Immediate recall relies heavily upon the stimuli initially being successfully encoded during the copy trial. Variable attention and concentration, impulsivity, and a poor executive approach all influence an individual's ability to effectively encode the target stimuli. Of than 9 subjects in the sample, 3(33.33%) displayed impaired performance on delayed recall of the complex figure design. Delayed recall measures one's ability to effectively retrieve information that was encoded and stored.

Processing Speed

Processing speed involves an individual's ability to process information rapidly and efficiently, without having to intentionally think through. Many tasks of processing speed involve measuring performance on tasks of over-learned material with relatively easy demands in a speeded fashion. For the current study, processing speed was measured by the D-KEFS Trail Making subtest: Visual Scanning, Number Sequencing and Letter Sequencing conditions, Color – Word Interference test: Color Naming, Word Reading conditions, and the Woodcock-Johnson III Test of Cognitive Abilities: Pair Cancellation subtest. All of the individuals in the sample (n = 9) scored within normal limits on all measures of processing speed. These findings suggest that chronic MA use does not consistently result in impaired performance on measures of processing speed.

Summary

Table 27 shows a summary of impaired neuropsychological performance by cognitive domain. Frequency analysis of impaired performance revealed the highest frequency of impairment at the≥1.5 SD level was found on the copy trial of the ROCF with 77.89% the sample exhibiting a significant discrepancy between estimates of premorbid IQ (also see Table 4). The ROCF copy trial requires sustained attention, planning skills, a good executive approach, and intact visuospatial construction abilities. These cognitive skills allow for individuals to effectively encode the visual stimuli for successful immediate and delayed recall. Only one individual (11%) showed impaired performance on another task of visuospatial construction abilities measured by the WAIS-III block design subtest (see Table 3). Impaired performance on the ROCF copy trial with this sample population most likely represents subtle attention difficulties and a poor executive approach rather than true

visuospatial construction impairment. Relative weaknesses in both attention and executive functioning have been associated with the effects of chronic MA use (Cobb et al., 2007). Test performance on the ROCF copy trial for all individuals in the sample (n = 9) are indicated on Table 4 in Standard Scores.

Impaired performance on measures of attention and concentration were noted with the second highest frequency of individuals performing ≥ 1.5 SD lower than their estimated premorbid IQ. Specifically, 4(50%) people in the sample were identified as making errors of omission with both auditory and visual stimuli (see Tables 20 & 21). Also a significant trend was noted for slowed average reaction times to target stimuli with frequencies of 3(37.5%) and 6(75%) out of 8 individuals in the sample with impaired performance for auditory and visual stimuli respectively.

Individual performance on measures of auditory/verbal episodic memory revealed low frequencies of impaired performance (at ≥ 1.5 SD level) for the sample. The most significant trend was identified as a relative weakness (not at the ≥1.5 SD level) for 5 of the 9 (55.56%) individuals in the sample on measures within the CVLT-II that require mental flexibility (Interference, List B). New learning may be slightly more difficult for MA users when required to switch from one source to another, taxing the executive functions of mental flexibility and attention. See Table 9 for individual performance on the CVLT-II List B trial.

A slightly higher frequency of individuals showed impaired performance compared to their estimated premorbid IQ on measures of visual memory. Table 27 shows frequencies of 2 out of 9(22.22%) and 3 out of 9 (33.33%) individuals in the sample displayed impaired performance on measures of immediate and delayed recall respectively. Further exploration of intrapersonal differences between these individuals and performance on the ROCF test

indicated that the same three individuals who showed either significant impairment or a relative weakness on both immediate and delayed recall all had impaired performance on the initial copy trial of the ROCF. This pattern of results suggests that these three individuals displayed impairment in visual memory due to poor encoding, most likely a result of a variable attention and a poor executive approach while copying the figure. Furthermore, their delayed recall was at the same level as their immediate recall suggesting that they were able to accurately retrieve the limited information initially encoded and stored.

These results also support the notion that cognitive deficits seen on measures of episodic memory both for auditory/verbal word lists and visual memory within this population are most likely a result of deficits in attention and components of higher order executive functioning (i.e. mental flexibility, set shifting, and interference) (Cobb et al., 2007). The findings from the current study suggest chronic MA users tend to show trends of impaired performance in attention, executive planning, and mental flexibility specifically when these tasks are involved as a component of another target task (i.e. episodic memory).

Table 2

Individual Performance on a Test of Psycho-Motor Speed

D-KEFS Trails

Condition 5 (Motor Speed) Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	100	Average	102
2	120	High Average	100
3	100	Average	87
4	110	Average	100
5	110	Average	102
6	110	Average	102
7	105	Average	95
8	90	Average	94
9	65*	Impaired	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 3

Individual Performance on a test of Speeded Visuoconstruction Abilities

WAIS-III: Block Design Subtest

Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	105	Average	102
2	123	Superior	100
3	87	Low Average	87
4	81	Low Average	100
5	108	Average	102
6	113	High Average	102
7	108	Average	95
8	73*	Borderline	94
9	102	Superior	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 4

Individual Performance on a test of Visuoconstruction Abilities and Executive Approach

Rey-Osterrieth Complex Figure (ROCF)

Copy Trial Subject (n = 9)	Standard Score	Percentile	Clinical Range	Estimated Premorbid IQ
1	70*	2	Borderline	102
2	76*	5	Borderline	100
3	76	5	Borderline	87
4	72*	3	Borderline	100
5	70*	2	Borderline	102
6	76*	5	Borderline	102
7	76	5	Borderline	95
8	67*	1	Impaired	94
9	76*	5	Borderline	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 5

Individual Performance on a test of Executive Functioning

Delis Kaplan Executive Function System (D-KEFS)

Color-Word Inhibition/Switching Trial			
Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	110	Average	102
2	90	Average	100
3	60*	Impaired	87
4	105	Average	100
5	115	High Average	102
6	105	Average	102
7	90	Average	95
8	105	Borderline	94
9	110	Superior	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 6

Individual Performance on a test of Visual Memory

Rey-Osterrieth Complex Figure (ROCF)

Immediate Recall Trial			
Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	84	Low Average	102
2	79	Borderline	100
3	91	Average	87
4	55*	Impaired	100
5	95	Average	102
6	102	Average	102
7	113	High Average	95
8	55*	Impaired	94
9	114	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 7

Individual Performance on a test of Visual Memory

Rey-Osterrieth Complex Figure (ROCF)

Delayed Recall Trial			
Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	84	Low Average	102
2	75*	Borderline	100
3	84	Low Average	87
4	69*	Impaired	100
5	95	Average	102
6	102	Average	102
7	103	Average	95
8	60*	Impaired	94
9	113	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 8

Individual Performance on a test of Auditory/Verbal Memory

California Verbal Learning Test-II (CVLT-II)

Trials 1-5 Total: (Learning) Trial Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	105	Average	102
2	72*	Borderline	100
3	105	Average	87
4	107	Average	100
5	93	Average	102
6	99	Average	102
7	103	Average	95
8	93	Average	94
9	115	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 9

Individual Performance on a test of Auditory/Verbal Memory

California Verbal Learning Test-II (CVLT-II)

Trial B: (Interference) Trial Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	85	Low Average	102
2	108	Average	100
3	85	Low Average	87
4	85	Low Average	100
5	85	Low Average	102
6	93	Average	102
7	55*	Impaired	95
8	78	Borderline	94
9	115	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 10

Individual Performance on a test of Auditory/Verbal Memory

California Verbal Learning Test-II (CVLT-II)

Short Delay Free Recall Trial			
Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	108	Average	102
2	85	Low Average	100
3	93	Average	87
4	108	Average	100
5	93	Average	102
6	78*	Borderline	102
7	115	High Average	95
8	108	Average	94
9	108	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 11

Individual Performance on a test of Auditory/Verbal Memory

California Verbal Learning Test-II (CVLT-II)

Short Delay Cued Recall Trial			
Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	108	Average	102
2	100	Average	100
3	93	Average	87
4	108	Average	100
5	108	Average	102
6	63*	Impaired	102
7	108	Average	95
8	100	Average	94
9	108	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 12

Individual Performance on a test of Auditory/Verbal Memory

California Verbal Learning Test-II (CVLT-II)

Long Delay Free Recall Trial			
Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	105	Average	102
2	71*	Borderline	100
3	100	Average	87
4	108	Average	100
5	93	Average	102
6	93	Average	102
7	100	Average	95
8	85	Low Average	94
9	115	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 13

Individual Performance on a test of Auditory/Verbal Memory

California Verbal Learning Test-II (CVLT-II)

False Positives			
Subject (n = 9)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	85	Low Average	102
2	55*	Impaired	100
3	100	Average	87
4	108	Average	100
5	85	Low Average	102
6	108	Average	102
7	100	Average	95
8	85	Low Average	94
9	93	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ

Table 14

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Auditory Prudence Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	92	Average	102
2	112	High Average	100
3	85	Low Average	87
4	78*	Borderline	100
5	95	Average	102
6	98	Average	102
7	86	Low Average	95
8	N/A		
9	96	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 15

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Visual Prudence Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	96	Average	102
2	87	Low Average	100
3	30*	Impaired	87
4	112	High Average	100
5	86	Low Average	102
6	104	Average	102
7	61*	Impaired	95
8	N/A		
9	108	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 16

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Auditory Consistency Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	112	High Average	102
2	111	High Average	100
3	57*	Impaired	87
4	98	Average	100
5	105	Average	102
6	129	Superior	102
7	102	Average	95
8	N/A		
9	105	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 17

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Visual Consistency Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	118	High Average	102
2	95	Average	100
3	64*	Impaired	87
4	103	Average	100
5	113	High Average	102
6	101	Average	102
7	106	Average	95
8	N/A		
9	98	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 18

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Auditory Stamina Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	102	Average	102
2	118	High Average	100
3	106	Average	87
4	106	Average	100
5	93	Average	102
6	89	Low Average	102
7	72*	Borderline	95
8	N/A		
9	132	Very Superior	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 19

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Visual Stamina Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	92	Average	102
2	132	Very Superior	100
3	62*	Impaired	87
4	102	Average	100
5	92	Average	102
6	88	Low Average	102
7	75	Borderline	95
8	N/A		
9	115	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 20

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Auditory Vigilance Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	105	Average	102
2	0*	Impaired/Invalid	100
3	60*	Impaired	87
4	0*	Impaired/Invalid	100
5	79*	Borderline	102
6	108	Average	102
7	107	Average	95
8	N/A		
9	107	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 21

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Visual Vigilance Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	106	Average	102
2	0*	Impaired/Invalid	100
3	0*	Impaired/invalid	87
4	65*	Impaired	100
5	103	Average	102
6	71*	Borderline	102
7	106	Average	95
8	N/A		
9	106	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 22

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Visual Focus Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	116	High Average	102
2	111	High Average	100
3	48*	Impaired	87
4	92	Average	100
5	120	Superior	102
6	105	Average	102
7	112	High Average	95
8	N/A		
9	114	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 23

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Auditory Speed Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	116	Average	102
2	15*	Impaired/Invalid	100
3	68	Impaired	87
4	60*	Impaired	100
5	67*	Impaired	102
6	84	Low Average	102
7	79	Borderline	95
8	N/A		
9	82	Low average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 24

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Visual Speed Scale Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	92	Average	102
2	0*	Impaired/Invalid	100
3	61*	Impaired	87
4	46*	Impaired	100
5	78*	Borderline	102
6	78*	Borderline	102
7	82	low Average	95
8	N/A		
9	60*	Impaired	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 25

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Full Scale Response Control Quotient Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	103	Average	102
2	119	High Average	100
3	41*	Impaired	87
4	100	Average	100
5	95	Average	102
6	103	Average	102
7	73*	Borderline	95
8	N/A		
9	115	High Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 26

Individual Performance on a test of Attention and Concentration

Integrated Visual and Auditory Continuous Performance Test (IVA)

Full Scale Attention Quotient			
Subject (n = 8)	Standard Score	Clinical Range	Estimated Premorbid IQ
1	106	Average	102
2	2*	Impaired/Invalid	100
3	17*	Impaired/Invalid	87
4	37*	Impaired	100
5	87	Low Average	102
6	91	Average	102
7	95	Average	95
8	N/A		
9	93	Average	102

Note: * Indicates ≥1.5 Standard Deviation difference from the Estimated Premorbid IQ
N/A Indicates a measure was not administered and results are not available

Table 27

Summary of Impaired Neuropsychological Performance by Cognitive Domain

Test by Cognitive Domain	Subjects with ≥1.5 SD Difference from Estimated IQ	% of Sample with deficit	Mean	(SD)
Motor Speed				
D-KEFS				
Trails Condition 5	1/9	11%	101.11	(15.96)
Visuoconstruction				
WAIS-III				
Block Design	1/9	11%	100.00	(16.23)
ROCF				
Copy Trial	7/9	77.89%	73.22	(3.35)
Attention/Concentration				
IVA				
Auditory Prudence	1/8	12.5 %	92.75	(10.26)
Visual Prudence	1/8	12.5 %	85.5	(27.63)
Auditory Consistency	1/8	12.5%	102.38	(20.59)
Visual Consistency	1/8	12.5%	99.75	(16.32)
Auditory Stamina	1/8	12.5%	102.25	(18.27)
Visual Stamina	1/8	12.5%	94.75	(21.95)
Auditory Vigilance	4/8*	50%	70.75	(46.88)
Visual Vigilance	4/8*	50%	69.63	(45.98)
Visual Focus	1/8	12.5%	102.25	(23.51)
Auditory Speed	3/8*	37.5%	69.25	(25.06)
Visual Speed	6/8*	75%	62.13	(29.06)
Full Scale Response Control Quotient	2/8*	25%	93.75	(25.10)
Full Scale Attention Quotient	3/8*	37.5%	66.00	(40.66)
Executive Functioning				
D-KEFS				
Color-Word Switching	1/9	11%	98.89	(16.91)
Memory				
Visual Memory				
ROCF				
Immediate Recall	2/9	22.22%	87.56	(21.88)
Delayed Recall	3/9	33.33%	87.22	(17.45)
Auditory Memory				
CVLT-II				
Total 1-5 (Learning)	1/9	11%	99.11	(12.29)
Trial B (Interference)	1/9	11%	85.22	(14.17)
Short Delay Free Recall	1/9	11%	99.56	(12.68)
Short Delay Cued Recall	1/9	11%	99.56	(14.73)
Long Delay Free Recall	1/9	11%	96.67	(13.12)
False Positives	1/9	11%	91	(13.12)

Note: *indicates totals which may be affected by invalid performance.

DISCUSSION

Conclusions

The purpose of the current study was to determine if chronic MA use produces a consistent profile of cognitive deficits. Several trends of impaired performance were identified within the sample population's cognitive profiles. A significant discrepancy between individual performance and estimated premorbid IQ was noted on measures of visuoconstruction, attention, concentration, and episodic memory.

The current sample of incarcerated MA users showed the most significant pattern of impairment on measures of visuoconstruction abilities with 7 of the 9(77.89%) individuals performing $\geq$ 1.5 standard deviations below their estimated premorbid IQ's established through the WTAR demographic prediction of premorbid intelligence. As with all neuropsychological test results, impaired performance should be confirmed by more than one data point and relative weaknesses should be considered when determining an individual's cognitive profile. Variability in cognitive strengths and relative weaknesses exist with all individuals and approximately 15% of intact individuals tend to display scores at least 1 SD below test means. Given these considerations, impaired performance on the ROCF for the majority of the sample likely represent difficulties with variable attention and a poor executive approach while constructing the figure, rather than a true impairment in visuoconstruction abilities. Only one individual within the sample also had impaired performance on another measure of visuoconstruction abilities (Block Design), while the rest of the sample displayed generally intact performance.

Performance on measures of attention and concentration revealed about 50% of the sample made errors of omission and had slowed reaction times to target stimuli. These results

suggest some MA users may tend to have difficulty sustaining attention and focusing diligently on mundane tasks over long periods of time.

Episodic visual memory deficits were also seen for approximately one third of the sample (2/9, 22.22% and 3/9, 33.33%) for immediate recall and delayed recall of visual stimuli, respectively. Deficits with accurately recalling and retrieving information most likely represent difficulty initially encoding the figure in the first place. Approximately three quarters of the sample (7 out of 9, 77.89%) had significant difficulty copying the figure accurately and efficiently. Poor attention to detail, not seeing the gestalt of the figure, and/or copying the figure in a piecemeal fashion all influence the efficiency in which visual stimuli is encoded. Given the nature of using archival data, behavioral observations and qualitative aspects of scoring were unavailable leaving these findings to be interpreted with caution.

Frequency analysis of cognitive performance suggests a pattern of decreased performance in the cognitive domains of attention and complex executive functioning. MA users may have lower scores on measures of episodic memory, and visuoconstructional abilities due to variable attention and subtle difficulties in executive functioning, especially when these cognitive abilities are utilized as part of a more complex task such as the ROCF test. Interestingly, results of the study also indicate the exact opposite in that MA users tend to do poorly on very simplistic, mundane tasks of attention that require focus over long periods of time (IVA CPT). These findings are both consistent with previous research suggesting MA use can produce very similar cognitive deficits as seen with individuals who have attention deficit hyperactivity disorder (Barr et al., 2006).

Limitations

The results of this study should be interpreted with caution as several serious limitations were present. First, the sample size consisted of only 9 individuals who met all of the strict inclusion and exclusion criteria. Given the small sample size, the results of this study cannot be generalized. However, these results may provide information regarding possible trends of impairment in several areas of cognitive functioning and more importantly, help to guide future research in this area with larger sample sizes. The use of a control group with larger sample sizes would significantly strengthen the integrity of the current study.

The present study utilized archival data for the analysis of cognitive performance of chronic MA users who consented to participate in neuropsychological testing for research purposes. The use of archival data also limited the accuracy in which individual premorbid estimates of IQ could be obtained. Ideally, the WTAR reading test in combination with the WTAR demographic prediction of FSIQ would have yielded the most reliable measure of estimated premorbid IQ. Instead, given the limited data available, only the WTAR demographic prediction of premorbid intelligence was used. According to Strauss et al. (2006), performance-based measures are susceptible to suboptimal effort. Therefore, the demographic based method of predicted estimated premorbid IQ was the most conservative method given the nature of the population and the use of archival data without access to behavioral observations or effort testing.

Another significant limitation was related to problems inherent with data gathered by self-report, specifically with this particular population. Individuals in the current study were given a substance abuse questionnaire inquiring about past drug and alcohol use and prominent drug of choice. The subjects selected for the current study indicated primarily

using MA as their drug of choice. Individuals who reported using other substances other than MA, alcohol and marijuana were excluded. The original data set consisted of 100 individuals but the final MA sample after meeting inclusion and exclusion criteria was only 9. It was too difficult to obtain a large sample of individuals who reported only using MA as this is virtually unheard of. For the purpose of this study individuals who reported some alcohol and/or marijuana use along with MA were included. Provided that the MA sample is not a "pure" MA sample, the results of this study may also reflect effects of alcohol and/or marijuana use. Furthermore, data regarding the frequency, amount, and specific route of administration of MA for the individuals in the sample were not available. These factors also significantly limit the extent to which the results of the current study can be interpreted and generalized.

The validity of some tests may have been compromised, specifically on measures of attention (i.e. IVA CPT) as some measures appeared significantly below expected levels for any population. The extremely low scores on specific measures within the IVA CPT may be a result of poor effort, and lack of motivation on some components of the test.

Future Directions

Some studies within the literature suggest cognitive deficits due to MA use can be transient and resolve over time: this may explain the scatter of impaired performance within the current study. Further research is greatly needed to determine the degree to which the quantity and frequency of MA use along with duration of abstinence may affect the recovery of cognitive deficits.

Future studies should also consider the high comorbidity of medical and psychiatric conditions typically found with individuals in substance using populations. Strict screening

of conditions that may affect cognitive functioning is essential in order to accurately identify true cognitive impairment resulting from chronic MA use. Difficulties inherent to studying the MA population include isolating cognitive impairment specifically due to MA use, as it is very rare that individuals only use MA and not other substances.

The majority of the MA sample in this study was found to have attentional deficits with errors of omission, slowed reaction time, and mild executive dysfunction. These deficits somewhat parallel the cognitive impairments often seen with individuals diagnosed with attention deficit hyperactivity disorder. The sample population was screened specifically for ADHD and those who had been diagnosed were excluded. Given the similar profile of impairment and high prevalence of individuals with ADHD found within the substance abusing population, it is essential that future studies also strictly screen for ADHD.

Review of the literature revealed that many studies lacked consistency in using the same tests to measure functioning in the different cognitive domains with this population. To some extent, conflicting outcomes between studies in the current body of literature may be a result of using different tests to measure the same cognitive domains. Different tests have varying levels of complexity and can tax other cognitive processes (i.e. attention and executive functioning with the CVLT or ROCF). Consistent use of the same measures for each cognitive domain would provide more reliable outcomes for determining a consistent profile of cognitive deficits for the MA population. Also, future studies may benefit from utilizing an effort test (i.e. Test of Memory Malingering, or Word Memory Test) to rule-out suboptimal effort and feigning, especially with incarcerated populations.

Determining a consistent profile of cognitive deficits for chronic MA users is an extremely difficult task which requires much more research with consistent use of measures,

stringent inclusion and exclusion criteria to isolate the effects of MA use, and large sample sizes with control groups in order to be truly generalized.

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